



Geochemical Model of CO₂ impact at the Well-Caprock-Reservoir interfaces.

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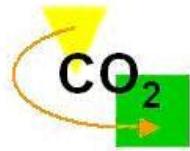
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Well – Reservoir – Cap rock INTERFACE

Modeling Cement CO₂-Alteration Mechanisms

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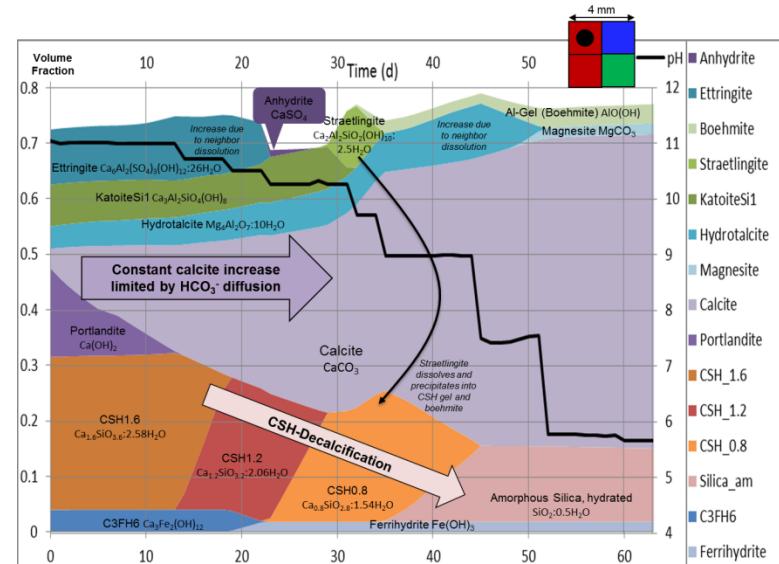
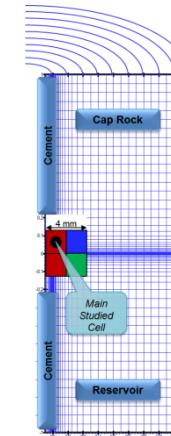
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INTERFACE CO₂-Mechanisms

- Agenda

- > Introduction
 - Objectives
- > Modeling Approach
 - Considered Scenario
 - Modeling tool
 - Geometry and Gridding
- > Results – Discussion
 - Illustration Parisian Basin
 - Cement Alteration Mechanisms
- > Conclusions
 - Limitations and Perspectives



INTERFACE CO₂-Mechanisms - Objectives

> ***Modeling Geochemical interactions due to CO₂ injection at the Well-Reservoir-Caprock INTERFACE***

- Characterization of reactions pathways
- Identification of new resulting minerals
- Chemical stability of cement-caprock interface
- Consequences in Porosity Evolution of the 3 zones

Modeling Approach - Scenario

- > Injection Well cement alteration due to **acid brine only**
 - CO₂ Injection downhole => Reservoir Brine acidification
- > **Diffusion only** of HCO₃⁻ and H⁺ (from CO_{2aq}), *no flow, no gas phase*
 - Cement degradation due to brine contact
 - Cement leaching due to caprock contact
- > Code Used : **ToughReact**
 - (finite volumes)
- > 1m*2m-scale *axisymmetric* model
 - 2753 cells
 - ΔR = ΔZ = 2 mm at the interface
 - Δt = 9 sec for kinetic convergence reasons

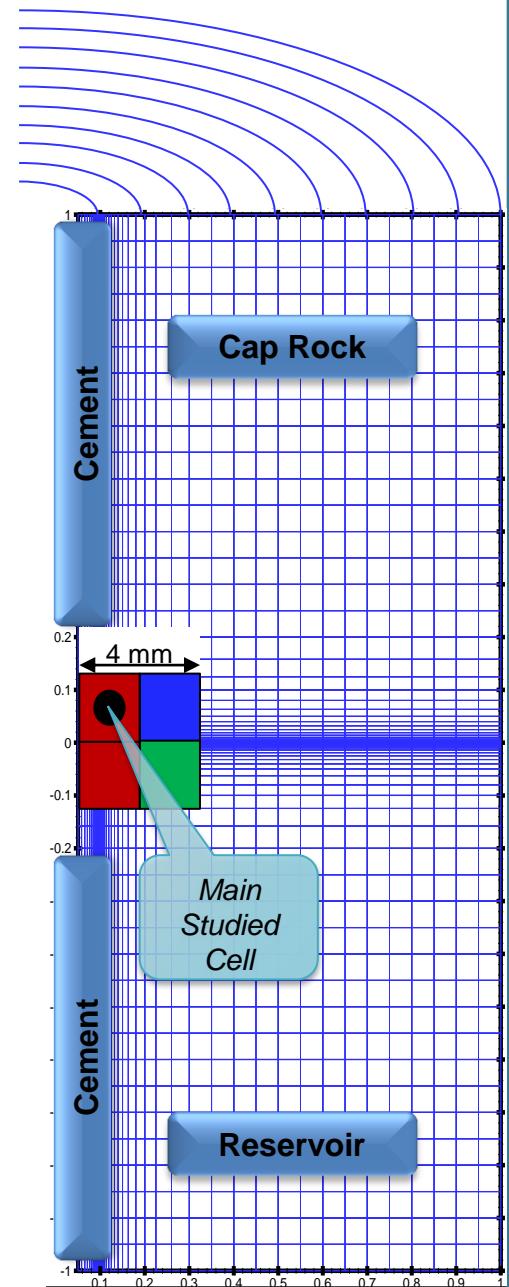


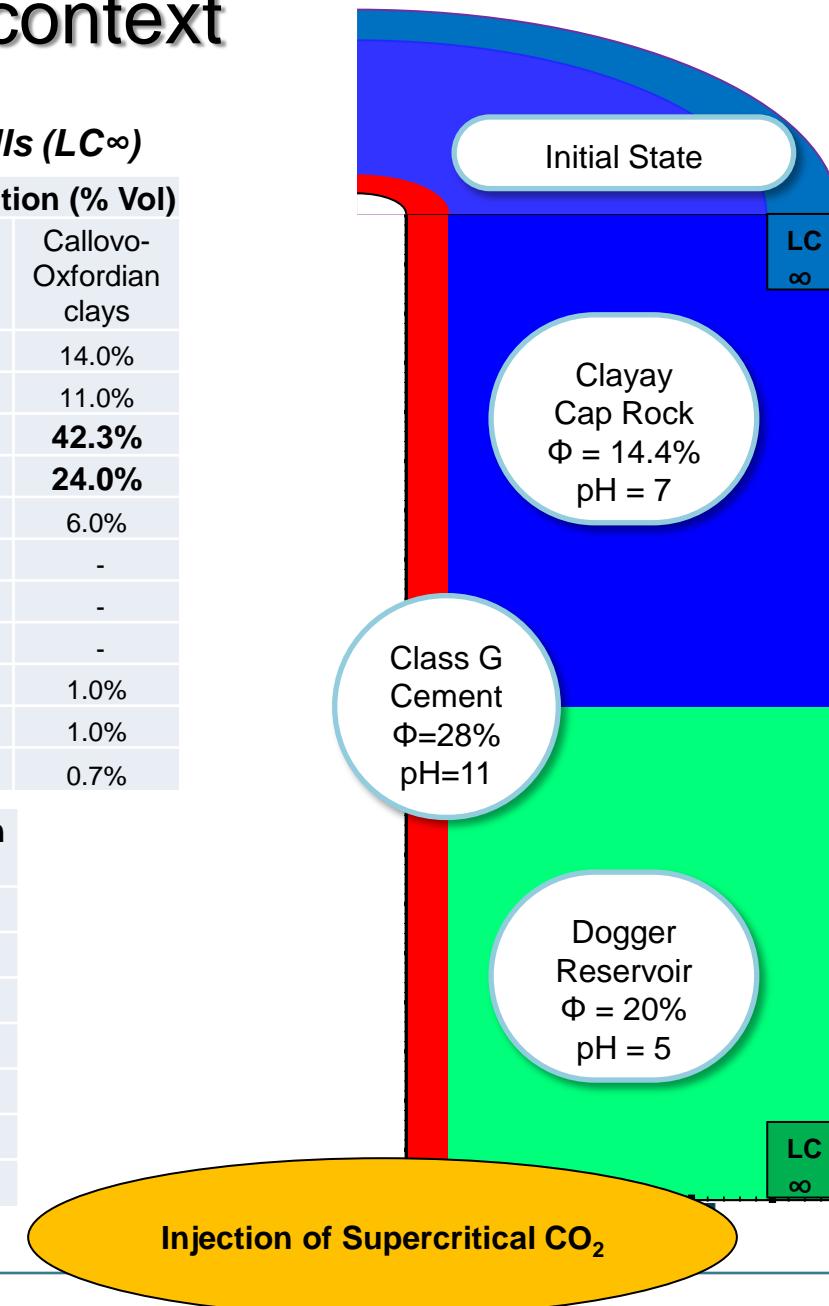
Illustration: Parisian Basin context

*Initial state, equilibrated water
at t=0 and at the 2 Limit Conditions border-Cells (LC ∞)*

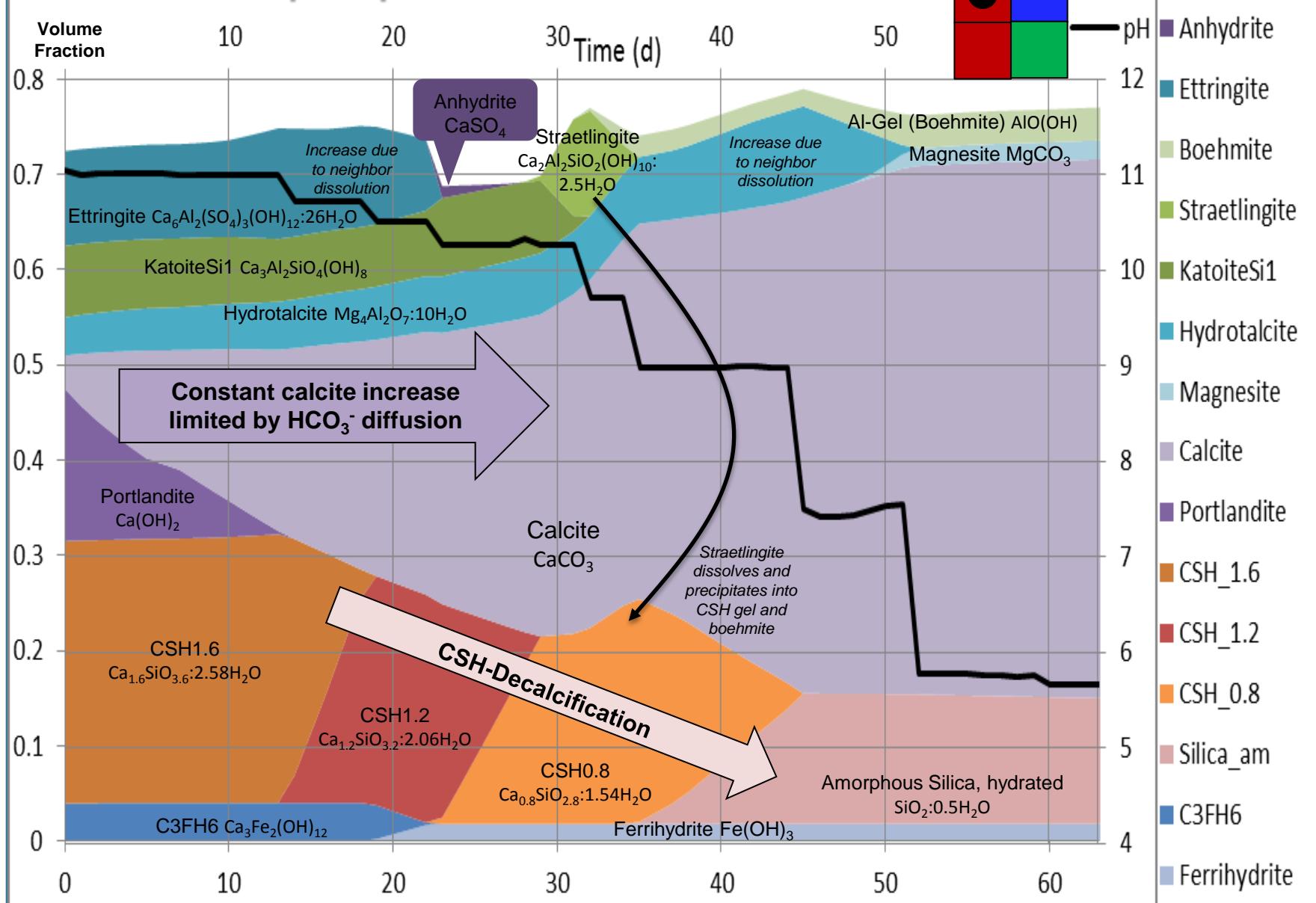
In-Situ Minerals	Formula	Composition (% Vol)	
		Dogger	Callovo-Oxfordian clays
Calcite	CaCO_3	77.5%	14.0%
Dolomite	$\text{CaMg}(\text{CO}_3)_2$	10.2%	11.0%
Illite-Mg	$\text{K}_{0.85}\text{Mg}_{0.25}\text{Al}_{2.35}\text{Si}_{3.4}\text{O}_{10}(\text{OH})_2$	0.1%	42.3%
Quartz	SiO_2	-	24.0%
Mg-Montmorillonite-Na	$\text{Na}_{0.33}\text{Mg}_3\text{Al}_{0.33}\text{Si}_{3.67}\text{O}_{10}(\text{OH})_2$	5.8%	6.0%
Siderite	FeCO_3	4.1%	-
Kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$	2.0%	-
Magnesite	MgCO_3	0.3%	-
Pyrite	FeS_2	-	1.0%
Chamosite	$\text{Fe}_5\text{Al}(\text{AlSi}_3)\text{O}_{10}(\text{OH})_8$	-	1.0%
Celestite	SrSO_4	-	0.7%

Class_G Cement	Formula	Composition (% Vol)
CSH_1.6	$\text{Ca}_{1.6}\text{SiO}_{3.6} \cdot 2.58\text{H}_2\text{O}$	38.1%
Portlandite	$\text{Ca}(\text{OH})_2$	26.1%
Ettringite	$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O}$	13.8%
Katoite_Si1	$\text{Ca}_3\text{Al}_2\text{SiO}_4(\text{OH})_8$	10.5%
C3FH6	$\text{Ca}_3\text{Fe}_2(\text{OH})_{12}$	5.5%
Hydrotalcite	$\text{Mg}_4\text{Al}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$	5.4%
Calcite	CaCO_3	0.6%

180 bar, 75°C, Salt = 25g/kg_w



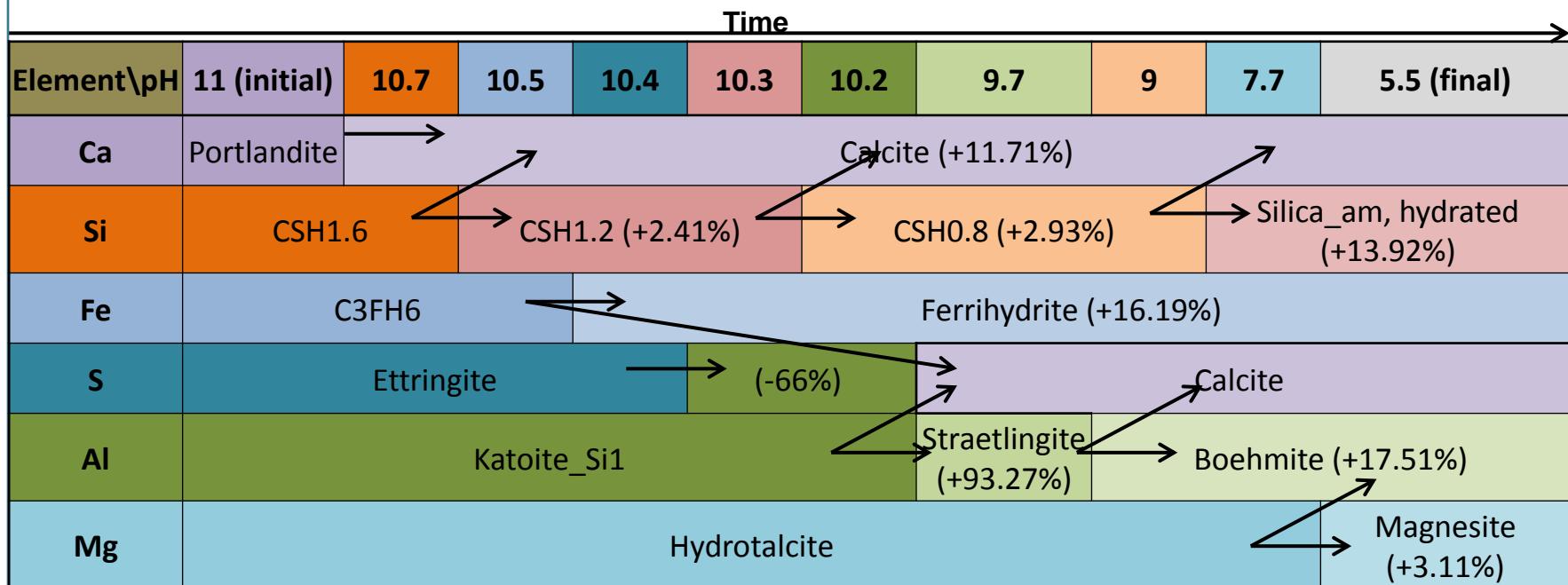
Results: triple point cement alteration



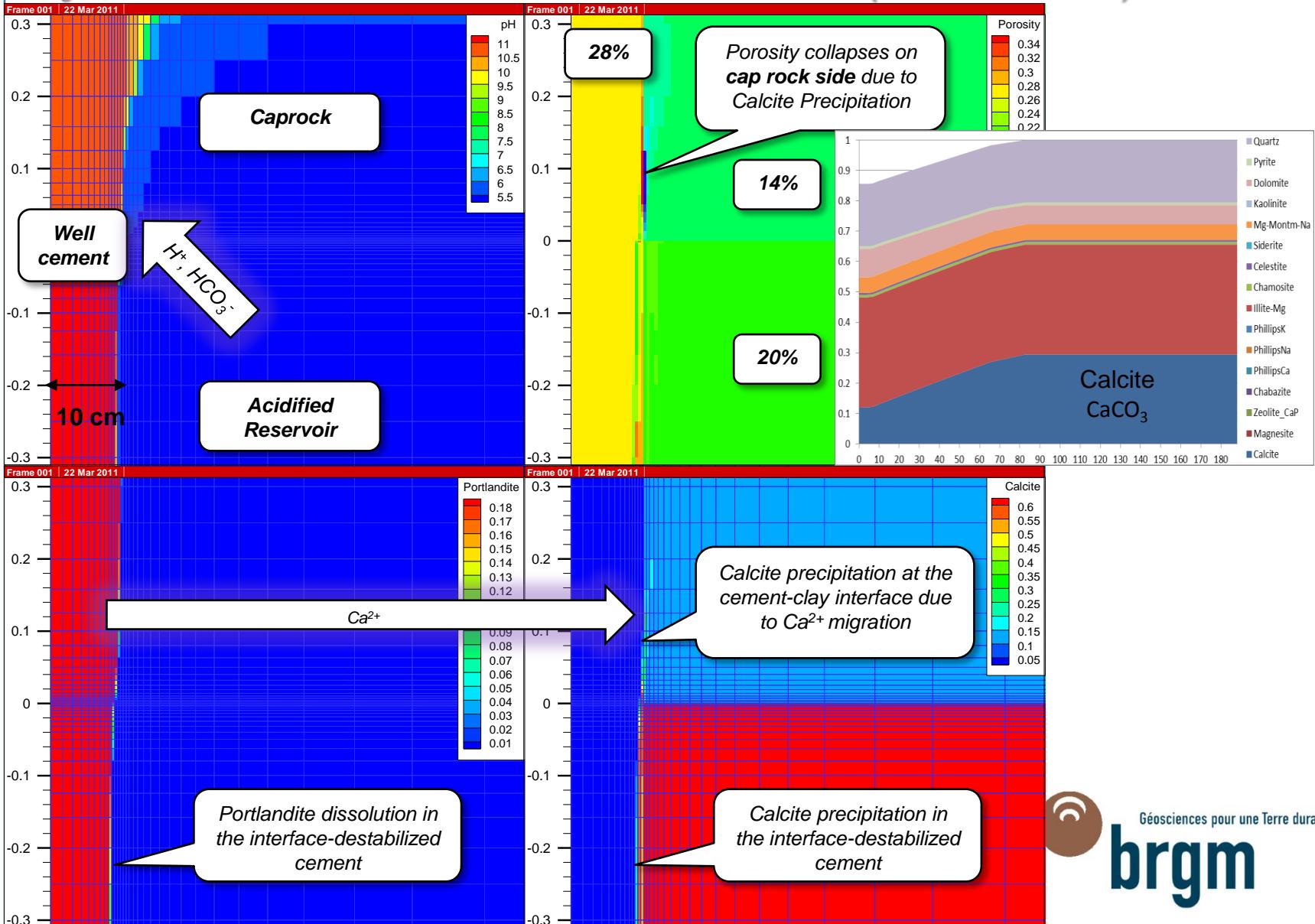
Mechanisms Analysis - pH-Buffering and Volumes

> Simplified Reaction pathway:

- H⁺ and HCO₃⁻ Diffusion is the limiting factor for the global cement degradation process
- pH is buffered successively by different mineral phases
- New created phases should occupy more Volume (%), but
- Liberated ions also migrate outside the cement



System Evolution after 3 months (Ref Case)



INTERFACE CO₂-Mechanisms - Conclusions

- > ***Determination of conceptual reaction pathway***
 - Possibility to extract simplified scheme to use it in a Poro-Mechanical study (part of the Project)
- > ***Sensibility Analysis done on the cement tortuosity***
 - Variation of the Damkholer Number (here diffusion/kinetics)
- > ***Limitations of the model:***
 - Cement carbonation produces a lot of H₂O (not considered in the mass/volume balance)
 - Gas phase not considered (some experiments show a stronger effect of wet CO₂ than acidified brine)
 - No heterogeneities